50. (New) The apparatus according to claim 47, wherein the at least one corona-discharge producing electrode pair comprises:

(i) a narrow-tipped, corona-producing cathode adapted to be electro-negatively energized, and

(ii) a broader surfaced anode adapted to be electro-positively energized relative to the cathode.

51. (New) The apparatus according to claim 47, wherein the reagent gas comprises nitrogen and the dielectric film formed is an oxynitride.

52. (New) The apparatus according to claim 51, wherein the substrate has a growing oxide layer exposed to the nitrogen for formation of the oxynitride film.

Remarks

The outstanding Official Action dated September 25, 2002 has been reviewed and amendments made where deemed appropriate.

Declaration, Specifications and Drawings

The examiner's objection to the declaration is not understood. It is not understood what is meant by "notary's signature of one of the inventors." Attorneys for applicant believe the examiner objects to the lack of declaration by the inventor Christopher T. Burns. A petition to prosecute this application in the absence of a missing inventor was filed on January 22, 2002. No action has been taken on that petition. In the meantime, attorneys for applicant were able to locate Mr. Burns and obtain his signature. His signed declaration accompanies this amendment.

The examiner's objections to the specification have been noted. Appropriate corrections have been made to pages 6 and 7. The numeral 7 has been deleted from line 17 of page 6 as suggested. On page 7 at line 2, the abbreviation IV has been replaced by current-voltage before the word "characteristics," a revision that is believed obvious from the context. The examiner's careful attention to the application is appreciated.

The examiner's objections to the drawings have been noted. A separate letter to the Official Draftsperson accompanies this amendment correcting Fig. 1 as indicated in red in the

accompanying copy. Again the examiner's care in examining the application is noted with gratitude.

Claim 1

The examiner's rejection of claim 1 under 35 U.S.C. § 102(b) is believed in error. This is inconsistent with applicant's election as acknowledged by the examiner at page 2 under "Election/Restrictions." Claim 1 has been withdrawn from further consideration, but at page 3 of the application the examiner rejects claim 1. This is not appropriate and that rejection should be withdrawn. Upon withdrawal of the rejection of nonelected claim 1 that claim will be cancelled without prejudice.

Rejection of claim 1 should further be withdrawn because it is in error. The Cappelli et al. reference does not teach subject matter of claim 1. The publication does not relate to a corona-discharge producing pair of electrodes but to a differing arcjet technology. Consequently, each of the examiner's comments in connection with the rejection as anticipated by Cappelli et al. is in error.

Claims 12 and 13

The examiner's rejection of claims 12 and 13 as unpatentable over Hinchliffe in view of Cappelli et al. under 35 U.S.C. § 103(a) has been noted. As presently amended, claim 12 calls for the distance from the corona formation to the substrate being such that substantially the only activated nitrogen molecules at that location are of the form $N_2A^3\Sigma_u^+$. This is not taught by either the Hinchliffe patent or the Cappelli et al. article. The two cannot be combined to include what can be found in neither.

In addition, throughout the claim rejections, the Cappelli et al. article has been cited as teaching those claimed features missing from the Hinchliffe patent. However, Cappelli et al. do not teach any provisions of apparatus establishing a corona discharge-supersonic free-jet. While the supersonic jets formed by the two processes are similar, the formation processes are not. The Cappelli et al. apparatus, while somewhat structurally similar to a corona discharge at first glance, nonetheless operates in a completely different regime of pressure, current, and voltage whereby it is termed an "arc discharge" rather than a "corona discharge." The inventor, Dr. Bruce Doak, points out that differences between these two types of discharges are so great that in

general no characteristics of arc-discharge production can be used to predict the behavior and performance of a corona discharge and so would not be "obvious to one of ordinary skill in the art." Consequently, the combining of features of the Hinchliffe patent and the Cappelli et al. publication were not obvious to the ordinarily skilled artisan at the time of the invention. Those outstanding rejections combining Hinchliffe and Cappelli et al. should be withdrawn.

The delivery to the substrate of substantially only the activated diatomic molecule of the form $N_2A^3\Sigma_u^+$, provides a very gentle layer formation procedure where one atom contributes to the layer being formed while the other carries away the heat of reaction rather than requiring the substrate and newly forming layer to dissipate that heat. The procedure accomplished by this apparatus is efficient in that a high percentage of the diatomic molecules contribute an atom. And thin, epitaxial coatings grown in this way are very high in quality.

Claim 13 is dependent from claim 12. Claim 13 patentably differs from Hinchliffe and Cappelli et al. for the reasons stated above with respect to claim 12. In addition, in claim 13 the corona discharge electrode proximate the nitrogen immersion orifice is a cathode. Hinchliffe teaches away from the use of a cathode. At column 10, lines 3 through 5, Hinchliffe says, "as reactant gas is supplied to the discharge nozzle 12 a positive polarity, DC high voltage simultaneously is supplied to the electrode 40." At column 7, lines 24 - 34, Hinchliffe advises that the electrode 40 should be an anode in order to limit the potential problem of sputter contamination. Hinchliffe specifically advises against the use of a cathode as the electrode 40 at lines 27 - 34 of column 7. Again at lines 46 - 50 of column 7, Hinchliffe refers to the DC power source 38 as "capable of supplying up to about 20,000 volts of a positive polarity to the electrode 40." Hinchliffe does not recognize or teach the advantage of the use of a negatively energized cathode for the corona-producing electrode located proximate the nozzle orifice. Applicant points to the advantage of this at page 9, lines 1 and 2 of the current specification. The applicant compares the use of positive versus negative voltage on the corona-producing electrode 26: "The positive corona was interrupted by continual flickering and sparking while the negative discharge was steady and stable." Since the Hinchliffe patent teaches away from the invention as set forth in claim 13, and because Cappelli et al. make no recommendation in this respect and are not concerned with the creation of a corona discharge, claim 13 is patentable over both of these alone or in combination.

Claims 14 - 18

Dependent claims 14 through 18 are patentable over Hinchliffe in combination with Cappelli et al. for the reasons set forth above with respect to claims 12 and 13. These claims have been rejected as unpatentable over Hinchliffe in view of Cappelli et al. and further in view of the Yamauchi et al. patent under 35 U.S.C. § 103(a). Yamauchi et al. teach the impingement of a pulsed stream of metastable helium atoms, not diatomic molecules or N_2. Yamauchi et al. do not, as the examiner suggests, "teach a corona discharge apparatus (Fig. 1) for depositing material on the surface of a substrate." Rather, Yamauchi et al. use the pulsed helium beam to cleanse the substrate surface. Yamauchi et al. do speak of use of their technology in depositing material on a substrate, but apparently only as a preliminary cleansing step, which is all that they describe. Like Hinchliffe and Cappelli et al., Yamauchi et al. fail to teach the location of the target substrate sufficiently distant from a corona discharge as to cause application of substantially only molecules, or even single atoms, having the $A^3\Sigma_u^+$ state. Consequently, by virtue of their dependence, claims 14, 15, 17 and 18 are patentable over the combination of Hinchliffe, Cappelli et al. and Yamauchi et al. since these cannot be combined to provide what is nowhere taught in any of the three cited references.

The examiner's citation of *In re Harza,* 274 F.2d 660, 124 USPQ 378 (CCPA 1960) concerning duplication of the downstream vacuum chambers is not applicable here where it is the distance to the target that is significant such that it permits sufficient time for the decay of molecules of excited states of lesser duration to evolve into either the $A^3\Sigma_u^+$ or ground state molecules by the time the targeted substrate is reached.

Claims 36 - 38

In the same way as the preceding claims, claims 36 through 38 patentably differ from Hinchliffe, Cappelli et al. and Yamauchi et al. taken individually or combined. Their rejection is now moot, it is urged. Unlike the three cited references, claim 36 makes it clear that diatomic nitrogen molecules of the form $N_2A^3\Sigma_u^+$ and $N_2X^1\Sigma_g^+$ are substantially the only nitrogen states at the location of the substrate. By their dependency, claims 37 and 38 are patentable on this basis, as well.

Claim 16

Regarding the examiner's rejection of claim 16 as unpatentable over Hinchliffe, Cappelli et al., Yamauchi et al., and the Bachir et al. article under 35 U.S.C. §103(a), it is respectfully urged that the Bachir et al. article does not overcome the deficiencies of Hinchliffe, Cappelli et al. and Yamauchi et al. as discussed above with respect to the claims from which claim 16 depends. Consequently, claim 16 is patentable, as well.

New Claims

New claims 39 - 41 are dependent from claim 36 and patentable on that basis as well as their content. Claims 42 - 46 are believed patentable by their dependence from claim 12 as well as their content. Claims 47 - 52 specifically set forth the production of an insulator film on the substrate, unlike the prior art of record. Claim 47, and claims 48 - 52, dependent from claim 47, are patentable over the art of record.

In view of the foregoing, it is respectfully urged that all of the claims now present in this application are patentable over the art of record and should be allowed at this time. Favorable reconsideration is requested.

Should the examiner have any questions or suggestions regarding this application, the examiner is invited to call or email the undersigned attorneys for applicant at the telephone number and email address listed below.

None of the revisions made herein is intended to forfeit or dedicate subject matter to the public.

A two-month extension of time in which to respond to the Official Action is requested in the accompanying Petition for Extension of Time, submitted in duplicate, and authorization is

hereby given to charge any additional fees associated with this communication to deposit account no. 070135. A duplicate copy of this sheet is enclosed.

Respectfully submitted,

Date: 2/14/03

By _____

Thomas D. MacBlain
Attorneys for Applicant
Registration No. 24,583

Gallagher & Kennedy, P.A.
2575 East Camelback Road
Phoenix, AZ 85016-9225
(602) 530-8088
tdm@gknet.com

Version With Markings to Show Changes:

In the specification:

Fig. 2 is a fragmentary diagrammatic illustration of an alternative embodiment of the supersonic corona discharge source of Fig. 1.

Detailed Description

In Fig. 1, a corona discharge supersonic free-jet source 20 has a quartz tube 22 (6 mm O.D., 4 mm I.D.), which has been heated and drawn to closure then ground back to form a nozzle orifice 23 with diameter of 200 μm as measured by an optical comparator. The tube 22 is mounted in a ¼" Swagelock cross 25 to allow as one electrode a tungsten or rhenium corona wire 26 (diameter 0.25 mm) to be inserted via a high voltage feedthrough 28 welded into the opposing leg of the cross. Source gas enters through one transverse leg 29 of the cross 25 as indicated at 31. The opposing leg 33 serves as the means of mounting the cross on a ¼" stud 34, all within a source vacuum chamber 36. The nozzle was operated at a stagnation pressure of typically 200-440 Torr, producing a background pressure of $1x10^{-6}$ torr in the source vacuum chamber 36 pumped by an 18,000 1/s diffusion pump 37. A circular auxiliary electrode 38 was positioned just downstream of the nozzle, outside of the free-jet boundary, to provide a point of attachment for the corona discharge. The discharge can be operated with the corona wire 26 either positive or negative with respect to the circular electrode 38. A current limited high voltage supply 39 to the corona wire was ballasted with a 250 kΩ [7] series resistor 41. Under these conditions a voltage of 4-6kV applied to the corona wire produces a discharge current of 6-18 mA and results in a readily discernible bright plume at the tip of the nozzle as diagrammatically shown at 42. The turn-on procedure is as follows. The source gas is raised to the desired pressure. The current limit of the high voltage power supply to the corona wire 26 is set to the desired discharge current. The voltage is raised until the discharge initiated, whereupon the current jumps immediately to the current limit, placing the power supply in its

current-limited mode. Once the discharge is struck, the emission current can be adjusted within bounds determined by the [IV] current-voltage characteristics of the discharge.

A custom-made refractory graphite skimmer 40, with a diameter 0.75 mm opening 43 at its apex, extracts the isentropic core of the free-jet plasma expansion to form a molecular beam. Skimmers of the kind used here are described in D.C. Jordan, R. Barling and R.B. Doak, Refractory Graphite Skimmers for Supersonic Free-jet, Supersonic Arc-jet, and Plasma Discharge Applications, 70 Rev. Sci. Instrum. 1640 (1999), incorporated herein by reference, and in U.S. provisional patent application Serial No. 60/092,815 of Jordan, Barling and Doak, filed June 8, 1998, also incorporated herein by reference. The shape and the very sharp edge of the front of the skimmer allow a shock wave to attach to the front of the skimmer. In this aerodynamic flow configuration, the central portion of the beam passes into and through the skimmer without being influenced by the skimmer edge. Further downstream of the skimmer, where the beam density is much less, simple apertures in flat plates can be used as collimators 52--52_n for further collimation of the beam. Downstream of the skimmer, several differentially pumped stages 44--44_n lead to a deposition chamber 46 where controlled growth can take place under UHV molecular beam epitaxy (MBE) conditions.

The differential pumping is employed to ensure that essentially only the collimated, directed beam provides reactants to the surface 49 of a target substrate 50 supported in a final chamber 46 by a suitable means for locating the substrate as is diagrammatically indicated at 51. Background gases in the various vacuum chambers 44--44_n also flow through a series of collimators 52--52_n separating one chamber from the next. As mentioned, these may be simply small openings in the wall separating one chamber from another or one or more may be a skimmer similar to the skimmer 40. There occurs what is called "effusion" of the background

In the claims:

12. (Amended) An apparatus for producing nitride films comprising:

(a) a pair of corona-discharge producing electrodes,

(b) a nitrogen delivery path leading to a [location] nozzle at which the electrodes produce a corona discharge, and

(c) means to locate a substrate along the nitrogen delivery path downstream of the location at which the electrodes produce the corona discharge for deposition thereon of nitrogen activated by the corona discharge at a location sufficiently distant from the corona-discharge producing electrodes such that essentially the only activated nitrogen impingent on the substrate is $N_2A^3\Sigma_u^+$.

13. (Amended) The apparatus according to claim 12, further comprising a nozzle with a nitrogen emersion orifice in the nitrogen delivery path, a first one of the corona-discharge electrodes being a cathode proximate the nitrogen emersion orifice of the nozzle, a second of the corona-discharge electrodes being spaced from the nitrogen emersion orifice of the nozzle and the first one of the corona-discharge electrodes, a skimmer located downstream of the nozzle in the direction of nitrogen flow, the skimmer defining an opening to collimate a beam of activated nitrogen molecules passing therethrough, at least one chamber downstream of the skimmer, means for evacuating the chamber to draw off gases other than the activated nitrogen molecules prior to the activated nitrogen molecules reaching the substrate.

14. (Amended) The apparatus according to claim 13, wherein the at least one chamber comprises one of a plurality of at least two succeeding chambers with means for evacuating each of the succeeding chambers to draw off gases other than the activated nitrogen molecules passing therethrough towards the substrate, each succeeding chamber in the direction of nitrogen flow being evacuated to a lower interior pressure, the last of the downstream chambers containing the means to locate a substrate and, in operation, containing at the location of the means to locate a substrate predominantly ground state N_2 molecules and $A^3\Sigma_u^+$ state metastable N_2 molecules, whereby the metastable N_2 molecules impacting a substrate deliver a single N atom, the further N atom of the N_2 pair carrying from the site of impact energy of reaction.

15. (Amended) The apparatus according to claim 14, wherein the nozzle comprises a restricted end of a tube, the tube being in the nitrogen delivery path, the [first one of the corona discharge electrodes] cathode being located within the tube, and the second of the corona discharge electrodes being electro-positive relative to the cathode and located outside the tube, the nitrogen emergent from the tube into a corona discharge between the electrodes forming with the corona discharge a corona discharge supersonic free-jet.

36. (Amended) Apparatus for producing a film on a semiconductor substrate comprising:

(a) means for establishing a vacuumized environment,

(b) means for establishing a corona discharge in the vacuumized environment,

(c) means for creating a [supersonic] flow of nitrogen gas into the corona discharge [to create] and a supersonic jet of diatomic, activated metastable nitrogen molecules from the corona discharge,

(d) means for collimating the jet of nitrogen molecules, and

(e) means for locating a target semiconductor substrate in the path of the collimated jet of nitrogen particles at a distance from the means for establishing a corona discharge such that substantially only diatomic nitrogen molecules of the form $N_2A^3\Sigma_u^+$ and $N_2X^1\Sigma_g^+$ are present at that distance.

39. (New) The apparatus according to claim 36, further comprising:

(f) means for controlling the temperature of the substrate.

40. (New) The apparatus according to claim 39, wherein the means for controlling the temperature comprises means for bringing the substrate to a temperature below 900° C.

41. (New) The apparatus according to claim 36, further comprising a source of a reagent in addition to the nitrogen for delivering the reagent to the substrate with the metastable nitrogen molecules to form on the substrate a layer that is a nitride of the reagent.

42. (New) The apparatus according to claim 12, further comprising at least one further corona-producing electrode and at least one further nitrogen delivery path to at least one further nozzle.

43. (New) The apparatus according to claim 42, wherein the pair of corona discharge electrodes, the at least one further corona-producing electrode, and the nitrogen delivery paths are part of an array of multiple, activated nitrogen molecule plasma production means opening into a vacuumized chamber.

44. (New) The apparatus according to claim 12, further comprising a source of nitrogen and argon in communication with the nitrogen delivery path, whereby a mixture of nitrogen and argon is delivered along the path to the substrate location.

45. (New) The apparatus according to claim 14, wherein, in operation, the pressure in each succeeding chamber is 1/10 or less than the preceding chamber.

46. (New) The apparatus according to claim 45, wherein the first chamber, into which the nozzle opens has a pressure less than 10^{-6} Torr.

47. (New) An apparatus for producing a dielectric insulator film comprising:

(a) at least one corona-discharge producing electrode pair,

(b) at least one source of a pressurized reagent gas,

(c) at least one path of reagent gas flow to at least one nozzle proximate the tip of one electrode of the at least one pair and in the region of corona discharge,

(d) a reduced pressure location at an outlet of the nozzle into which the reagent gas emerges as a supersonic jet of activated reagent molecules,

(e) a skimmer downstream of the nozzle in the direction of flow of the supersonic jet, and

(f) a substrate location downstream of the skimmer, in operation locating a substrate for formation thereon a dielectric film composed at least in part of the reagent.

48. (New) The apparatus according to claim 47, wherein the substrate location is at a distance downstream of the nozzle such that the activated reagent molecules are substantially only ground state molecules and activated molecules of the $A^3\Sigma_u^+$ state.

49. (New) The apparatus according to claim 48, wherein the at least one source of a pressurized reagent gas is a source of diatomic molecules of reagent gas, the activated molecules arriving at the substrate location are diatomic molecules of the $A^3\Sigma_u^+$ state.

50. (New) The apparatus according to claim 47, wherein the corona-discharge producing electrode pair comprises:

(i) a narrow-tipped, corona-producing cathode adapted to be electro-negatively energized, and

(ii) a broader surfaced anode adapted to be electro-positively energized relative to the cathode.

51. (New) The apparatus according to claim 47, wherein the reagent gas comprises nitrogen and the dielectric film formed is an oxynitride.

52. (New) The apparatus according to claim 51, wherein the substrate has a growing oxide layer exposed to the nitrogen for formation of the oxynitride film.